A simple bound for the variation of the closest approach of a small body and a star due to general relativity

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As a comet, asteroid, or planet approaches its parent star, the orbit changes shape due to the curvature of spacetime. For comets in particular, the deviation at the pericentre may noticeably change their ephemerides and affect the dynamics of outgassing, tidal disruption or other processes which act on orbital timescales and are assumed to follow Newtonian gravity. I derive a simple analytic expression for the maximum deviation in terms of only the stellar mass and eccentricity of the orbit:

$$\Delta_{\max} \approx 2.95 \text{ km} \left(\frac{M_\star}{M_\odot}\right) \frac{(e^2 + 8e - 3)}{(1+e)^2} \quad (1)$$

Here, e is the orbital eccentricity and the quantity Δ represents the actual closest encounter distance (including relativity) minus the closest encounter distance predicted by Newtonian gravity alone. This relation can be used to assess the potential importance of including short-period relativistic terms in models containing comets, asteroids or planets, and help determine the level of precision needed in numerical integrations. The magnitude of the deviation in the Solar system is typically comparable to the size of comet nuclei, and the direction of the deviation is determined by the eccentricity.

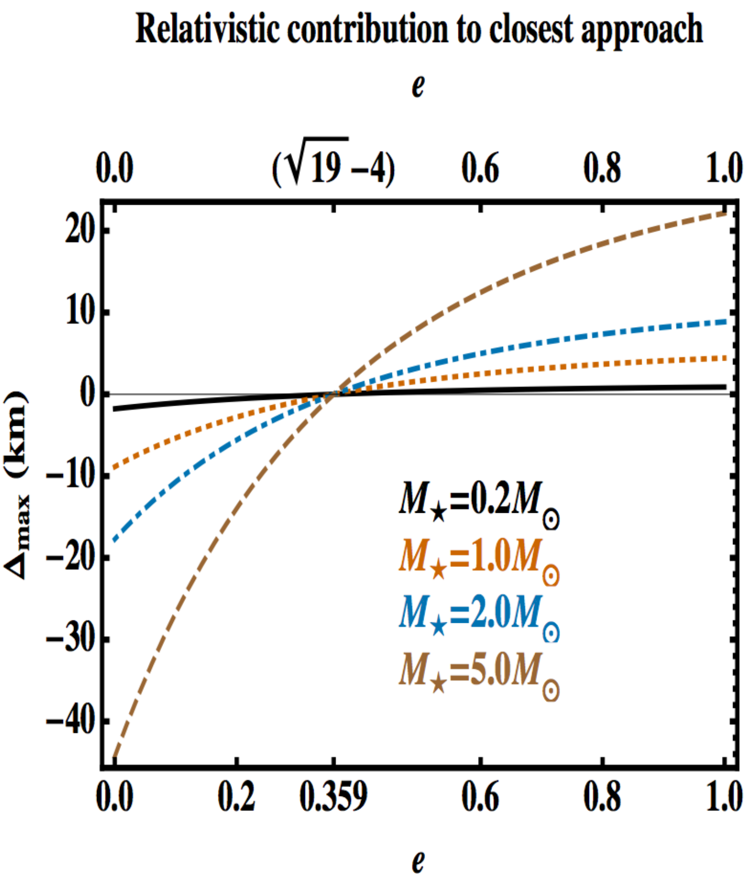

Figure: How the orbital pericentre changes when effects from general relativity are included.

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